Visual Classification of Benthic Habitats in the US Virgin Islands and Puerto Rico

1.0 Introduction

Benthic habitat maps around the US Virgin Islands and southwest of Puerto Rico are being produced by the National Ocean Service's (NOS) Center for Coastal Monitoring and Assessment (CCMA). These maps use acoustic data from multibeam sonar to differentiate and ultimately delineate distinct benthic habitats (e.g. sand, spur and groove reef, patch reef) based on spatial patterns in bathymetry and sonar reflectance (backscatter). To ensure the maps are accurate, in situ visual classifications of the seafloor are used to groundtruth benthic habitats and to assess map accuracy. Due to the range of depths involved, classifications were carried out using video imagery collected from towed platforms and remotely operated vehicles (ROVs).

2.0 Sampling Design

The towed platforms and ROVs collected in situ imagery data using along underwater transects. Two independent sets of transects were used. One set of transects was used to groundtruth acoustic data. These transects were purposefully placed over as many distinct habitat features and habitat transitional areas as possible. Distinct habitat features and transitional areas were determined from spatial patterns in fine-scale NOS bathymetry data (NOS, 2004; 2005; 2006). In rare cases when fine-scale data was not available, coarser-scale bathymetry data from GEODAS (GEODAS, 2005) was used. A second set of transects was used to assess the accuracy of benthic maps. Transects in this set were randomly positioned in the mapped areas. Due to logistical constraints all transects were typically positioned along a bathymetric contour and in line with predominant current and wind vectors. Summary information of the "groundtruthing" and "accuracy assessment" transects completed in each year per survey area are shown in **Table 1**.

3.0 Benthic Habitat Classification

Benthic habitats will be classified by geomorphological structure, biological cover, geographical zone and slope. Only geomorphological structure and biological cover will be interpreted by observers from video imagery. Geographical zone will be determined based on the relative position of features to neighboring features and slope will be determined from bathymetry data (NOS, 2004; 2005; 2006). A list of possible categories is provided in **Table 2**.

A hierarchy of geomorphological structure types is used to classify benthic habitats. At its coarsest scale, the benthic habitat maps are divided into "hard bottom", "soft bottom" and "other" types. Each of these is further divided into numerous subcategories (see **Table 2**). The list of geomorphological structure types incorporate contributions from Green et al. (1999), Kendall et al. (2004) and a preliminary assessment of video data to identify which benthic habitat types were present.

Biological cover is divided into 11 categories (see **Table 2**). These are quantified (if present) using the following groupings:

A. Absent (0%)

B. Rare (1%-10%)
C. Sparse (10%-50%)
D. Patchy (50%-90%)
E. Continuous (90%-100%)
F. Unknown

Complementary data on rugosity (vertical range of benthic structures) is quantified using the following categories:

A. Low (0 cm – 30 cm)
B. Moderate (30 cm – 100 cm)
C. High (>100 cm)

4.0 Benthic Habitat Characterization Methods

All observer characterizations corresponded to dimensions which define the envisioned benthic habitat map's minimum mapping unit (MMU) (i.e. map spatial resolution). A range of MMUs, which increased in size with depth were used to accurately map benthic habitats (see **Table 3**). The MMUs were determined by the spatial resolution of data used to make the map – multibeam sonar signals (see **Table 3**). Since the spatial resolution of sonar signals became coarser at deeper depths the MMU size increased with depth. A single MMU was not employed, because either spatial resolution would be lost at shallower depths or characterizations would be inappropriate for deeper sites.

This project was conducted over multiple years and due to varying logistical and equipment constraints, visual characterization methods used to assess geomorphological structure type, biological cover and rugosity differed among field missions (see **Table 4**). The distinct methods are described below.

4.1 Methods in 2004

The NOAA ship Nancy Foster was used to collect underwater video of benthic habitats from February 22 to March 1, 2004. Video was acquired using a downward pointing camera mounted on a towed underwater platform - the MiniBat. The MiniBat provided limited control of depth and was used to position the camera relatively close to the bottom (range 0.5 m to 10 m, average 3 m). Time, ship velocity, tow cable length, and shipboard GPS coordinates were recorded along with the video. This supplemental data was used to estimate the MiniBat's geographic position using a layback method. Similar studies have estimated positional accuracy using the layback method is within 50 m (CRED, 2001). All video was taken during daylight hours to guarantee sufficient ambient light levels, because the towed platform did not have its own light source. The video data was interpreted according to **Protocol #1**. An inability to effectively maneuver the towed MiniBat meant that it could not consistently see the bottom and thus a large proportion of the video could not be interpreted.

4.2 Methods in 2005

A video camera and high-resolution digital still camera mounted on a Spectrum Phantom S2 Remotely Operated Vehicle (ROV) was used to collect video and still image data, respectively. Data was collected using the NOAA ship Nancy Foster from February 1 to 12, 2005 predominantly during daylight hours to ensure adequate ambient light levels. High powered strobe lights mounted on the ROV were used to supplement ambient light levels during the day and served as the only source of light during night operations. The video data and images were interpreted according to **Protocol #2**. An Ultra Short Baseline (USBL) system was used to determine the relative position of the ROV to the Nancy Foster, and in conjunction with the ship's dynamic positioning system, the geographic position. The positional accuracy was estimated to be within 5 m for the maximum depth surveyed (200m).

Video data was collected throughout the duration of a transect and photo stills were collected at first 1 minute (first 2 transects) and later 30 second intervals. The forward-facing video camera was pointed at a 45 degree downward angle to give ROV pilots a view of upcoming obstacles and researchers a view of the benthic habitat. The ROV height above the substrate and speed were approximately 2 m and 1 m/s, respectively. The ROV pilot attempted to keep the ROV height and speed as constant as possible to standardize the field of view and spatial resolution of characterizations. Two downward pointing parallel lasers separated by 5 cm and the scale of habitat features and organisms were used to estimate height off the bottom. Still photo images were acquired using a downward pointed camera. The uniform distance between lasers was used in photo characterizations as a scale reference.

4.3 Methods in 2006

Video images of benthic habitat were taken during a March 21 – April 2, 2006 cruise on the NOAA ship Nancy Foster. A SeaEye Falcon ROV was used to acquire video at depths between 20 m and 800 m. A forward mounted, ±90° tilting camera was used to both drive the ROV and collect images for subsequent characterization. The ROV collected video data along predefined transects that typically ran parallel to isobaths, because of the time needed to change the ROV's position in the water column. ROV speed was variable, but always under 1 m/s. ROV distance from the bottom was on average 1 m. The video camera was predominantly positioned at -60 from horizontal to provide the best view for benthic habitat characterization and driving, but was positioned horizontally when the ROV moved sideways along steep (>70 °) cliffs. High powered lights were used to allow visual characterization. The video data was interpreted according to **Protocol #3**. A USBL system was used to determine the relative position of the ROV to the Nancy Foster, and in conjunction with the ship's dynamic positioning system, the geographic position. The positional accuracy of the USBL is dependent on depth and therefore accuracy was estimated to range between 5 m at a depth of 200 m to approximately 50 m at a depth of 800 m.

Since very little work has been done to date on the deep-sea environment in the surveyed areas, video data was also used to inventory deep-sea organisms and objects. The inventory work recorded observations of a multitude of deep-sea organisms, processes and objects including:

A. Fish and if possible their taxonomic ID
B. Mobile invertebrates (e.g. jellyfish, lobster, squid, crinoids, sea stars) and if possible taxonomic ID
C. Tracks or holes in soft sediment
D. Mounds of soft sediment
E. Trash

F. Fishing gear
G. Compacted Mud
H. Sediment covering bedrock
I. Other (Specify in notes)

5.0 References

CRED, 2001. Coral Reef Ecosystem Division (CRED). Operational Overview Mapping in Depths >20m. URL: http://www.pifsc.noaa.gov/cred/hmapping/map_system.php, (Accessed, 6/5/06).

GEODAS, 2005. NOAA's GEOphysical DAta System (GEODAS). URL: http://www.ngdc.noaa.gov/mgg/geodas/geodas.html, (Accessed, 6/5/06).

Kendall, M.S., M.E. Monaco, K.R. Buja, J.D. Christensen, C.R. Kruer, and M. Finkbeiner, R.A. Warner. 2001. (On-line). Methods Used to Map the Benthic Habitats of
Puerto Rico and the U.S. Virgin Islands. URL: http://biogeo.nos.noaa.gov/projects/mapping/caribbean/startup.htm.

NOS, 2004. Characterization of NPS National Coral Reef Ecosystem Monuments in the U.S. Virgin Islands (USVI): R/V Nancy Foster Mission 2004. Website http://ccma.nos.noaa.gov/products/biogeography/usvi_nps_2004/welcome.html, (Accessed, 6/5/06).

NOS, 2005. Characterization of NPS National Coral Reef Ecosystem Monuments in the U.S. Virgin Islands (USVI): R/V Nancy Foster Mission 2005. URL: http://ccma.nos.noaa.gov/products/biogeography/usvi_nps_2005/welcome.html, (Accessed, 6/5/06).

NOS, 2006. Characterization of NPS National Coral Reef Ecosystem Monuments in the U.S. Virgin Islands (USVI) and Puerto Rico: R/V Nancy Foster Mission 2006. URL: http://ccma.nos.noaa.gov/products/biogeography/usvi_nps_2006/welcome.html, (Accessed, 6/5/06).

Protocol #1

1) Record the following information
    a. Start time
    b. End time
    c. Transect ID
    d. Region
    e. Target depth(s)
    f. Transect notes (e.g. no USBL, use of ROV garage)
2) Begin video at start time and play video until seafloor can be seen
3) Pause video and capture frame as still image
4) Record the following information from the still image
    a. Time
    b. Bearing
    c. Depth
    d. Geomorphological structure type according to **Table 2**
    e. Rugosity level according to **Table 2**
    f. Quantity of total biological cover and biotic groupings according to **Table 2**
    g. Notes - any expanded description of benthic habitat when classification system is inadequate (i.e. modifier) or expanded description of inventory item (i.e. species of fish) or new inventory item not in selection
5) Play video again for exactly 1 minute
6) Repeat steps 3 to 5 until end of transect

Protocol #2

1) Record the following information
    a. Start time
    b. End time
    c. Transect ID
    d. Region
    e. Target depth(s)
    f. Transect notes (e.g. no USBL, use of ROV garage)
2) Open and examine a still image (starting from the first)
3) Record the following information from still image
    a. Time
    b. Quantity of total biological cover and biotic groupings according to **Table 2**
4) Begin video and forward to time of characterized image
5) Pause video and record the following information from video image
    a. Time
    b. Bearing
    c. Depth
    d. Geomorphological structure type according to **Table 2**
    e. Rugosity level according to **Table 2**
    f. Notes - any expanded description of benthic habitat when classification system is inadequate (i.e. modifier) or expanded description of inventory item (i.e. species of fish) or new inventory item not in selection
6) Repeat steps 2 to 5 until all still images have been interpreted

Protocol #3

1) Record the following information
    a. Start time
    b. End time
    c. Transect ID
    d. Region
    e. Target depth(s)
    f. Transect notes (e.g. no USBL, use of ROV garage)
2) Begin video at start time and play video until seafloor can be seen
3) Pause video and capture frame as still image
4) Record the following information from the still image
    a. Time
    b. Bearing
    c. Depth
    d. Geomorphological structure type
    e. Rugosity level
    f. Quantity of total biological cover and biotic groupings according to **Table 2**.
    g. All visible inventory items according to **Table 2**
    h. Notes – any expanded description of benthic habitat when classification system is inadequate (i.e. modifier) or expanded description of inventory item (i.e. species of fish) or new inventory item not in selection.
6) Play video until a benthic habitat record changes
7) Repeat steps 3 to 6.
8) Record time at end of video

Table 1: Summary information of "groundtruthing" and "accuracy assessment" transects completed in each year per survey area (A – St Croix / Buck Island Reef National Monument; B – South St. John / South St. Thomas / Mid-Shelf Reef / Grammanik Bank; C – SW Puerto Rico).

(A)

	Groundtruthing Transects		Accuracy Assessment Transects	
Year	Number	Cumulative Length	Number	Cumulative Length
2004	1	8.2	0	N/A
2005	4	4.0	2	1.8
2006	5	7.2	3	3.3

(B)

	Groundtruthing Transects		Accuracy Assessment Transects	
Year	Number	Cumulative Length	Number	Cumulative Length
2004	6	21.7	0	N/A
2005	15	31.1	16	29.2

(C)

	Groundtruthing Transects		Accuracy Assessment Transects	
Year	Number	Cumulative Length	Number	Cumulative Length
2006	5	6.3	6	6.8

Table 2: Benthic habitat classification system used for mapping.

Geomorphological Structure Type

A. Unconsolidated Sediment
    1. Sand
    2. Mud

B. Coral Reef and Hardbottom
    1. Linear Reef
    2. Spur and Groove
    3. Patch Reefs
        i. Individual
        ii. Aggregated
    4. Scattered Coral/Rock in unconsolidated sediment
    5. Reef Rubble
    6. Pavement
    7. Pavement with Sand Channels
    8. Bedrock
    9. Isolated Rock/Boulder

C. Other
    1. Unknown
    2. Concealed

Biological Cover Types

A. Live hard coral (Stony Corals, Hydrocorals)
B. Live soft coral (Gorgonians, Black Coral)
C. Sponge
D. Seagrass
E. Macroalgae
F. Coralline algae
G. Turf algae
H. Emergent vegetation
I. Sessile cnidarians, segmented worms and crinoids
J. Uncolonized
K. Unknown

Geographical Zone Type

A. Shoreline/Intertidal
B. Vertical Wall, Overhang, Ledge
C. Lagoon
D. Back Reef
E. Reef Flat
F. Reef Crest
G. Fore Reef
H. Bank/Shelf
I. Bank/Shelf Escarpment
J. Channel, Rill, Gully
K. Terrace
L. Alluvial Fan
M. Dredged
N. Land
O. Unknown

Slope

A. <5°
B. 5°-30°
C. 30°-45°
D. 45-90°
E. >90°
F. Unknown

Table 3: MMUs for distinct mapped depth ranges.

Depth Range (m)	Minimum Mapping Unit Size (m)
0 – 50	2 X 2
50 – 250	5 X 5
250 – 1000	10 X 10

Table 4: Summary of characterization methods and surveyed depths by year.

Year	Platform	Instruments	Depths Characterized (m)
2004	MiniBat – towed underwater camera	Video camera	20 – 100
2005	Phantom II – Remotely Operated Vehicle	Video camera and still camera	20 – 200
2006	SeaEye Falcon – Remotely Operated Vehicle	Video camera	20 – 1000